Part VII. Risk Assessment

A. Hazard Identification

The first step in risk assessment is identifying the hazards that could affect the Wasatch Front region. Hazard identification addresses the geographic extent, the intensity/magnitude of a hazard and the probability of its occurrence. Hazard identification was initiated through an extensive process that utilized the following:

- Core Planning Team
- Local Working Groups
- Technical Team
- Community and Public individuals
- Elected Officials
- City and County Agencies
- Utah Division of Homeland Security
- Utah Geological Survey
- Utah Automated Geographic Reference Center

The natural hazards in Table 7-1 (next page) have the potential of affecting each county within the Wasatch Front region. The identification process for each county and participating jurisdictions utilized those natural hazards that consistently affected each county prior to and during the planning process based on history of occurrences, future probability, and risk. Table 7-2 (page 73) identifies those hazards on a county level for easy reference.

The Wasatch Front Regional Council, with help from local officials, created maps that identified the location of critical facilities and the municipalities affected by each identified hazard. Initial data from this study was also used to determine hazards that presented the greatest risk to each of the counties. The geographic extent of each hazard is identified through maps in every county section. The hazard intensity/magnitude and probability profiles are also found in each county section.

County jurisdictions contributed to the risk assessment analyses performed for the county when located within an identified hazard boundary (See Section E). Drought, infestation and severe weather are considered regional hazards and have been profiled as such.

Hazard	How Identified	Why Identified
Earthquake	• Review of County Emergency Operations Plans • Review of past disaster declarations • Input from City and County Emergency Operations Managers, USGS, UGS, Utah DHLS, and community members	• Utah has a 1/5 chance, of experiencing a large earthquake within the next fifty years. • Numerous faults throughout Utah including the Intermountain Seismic Zone. • Yearly, Utah averages approximately 13 earthquakes having a magnitude 3.0 or greater. • Earthquakes can create fire, flooding, hazardous materials incident, transportation, and communication limitations. • The Wasatch Front has recorded large earthquakes in the past and can be expected to experience large earthquakes in the future.
Landslide	• Input from City and County Emergency Operations Managers, USGS, UGS, NCDC, Utah DHLS, and community members	• Have caused damage in the past to residential and commercial infrastructure. • Can be life threatening. • Generally occur in known historic locations therefore risks exist throughout much of the Wasatch Front. • To increase community awareness.
Wildland Fire	• Review of County Emergency Operations Plans • Review of Community Wildfire Plans • Input from County Emergency Managers, Utah DHLS, Utah FFSL, Utah FS, NWS, FEMA, and local community members	• Serious threat to life and property. • Increasing threat due to urban growth in WUI areas. • Secondary threat associated with flooding, drought, and earthquake • Most of Utah is at risk including the growing counties of the Wasatch Front region. • Additional funding and resources offered by local and state agencie to reduce risk. • To increase community awareness.
Problem Soils	• Review of County Emergency Operations Plans • Input from community members, Utah, DHLS, and UGS • Researched historical data	• Related to subsequent effects from earthquakes. • Have affected infrastructure and local economy in the past.
Dam Failure	• Review of County Emergency Operations Plans • Input from community members, Utah DWS, Dam Safety Section, Utah DHLS • Review of inundation maps	• Can cause serious damage to life and property and have subsequen effects such as flooding, fire, debris flow, etc.. • Many reservoirs located in the five county region of the Wasatch Fron • Threat to downhill communities. • Subsequent effects include flooding, fire, and debris flows. • To increase community awareness. • To incorporate mitigation measures into existing plans to help serve local residents.
Flood	• Review of past disaster declarations • Input from City and County Emergency Operations Managers, Utah DWS, UGS, Utah Army Corps of Engineers, Utah DHLS, and community members • Review of Flood Insurance Studies, Floodplain maps, and Flood Insurance Rate Maps	• Several incidents have caused severe damage and loss of life. • Many of the rivers and streams are located near neighborhoods. • Many neighborhoods are located on floodplains, alluvial fans. • Topography and climate lead to cloudburst storms and heavy precipitation can result in flash flooding throughout most of the Wasatch Front.

Table 7-1. Local Hazards Identification

Hazard	How Identified	Why Identified
Drought	• Review of Utah State Water Plan • Input from community members, Utah DHLS, NWS, NCC, and NCDC	• Affects local economy and residents. • Reduces available water in reservoirs impacting culinary, irrigation, and municipal water supplies. • Drought periods may extend several years. • Secondary threat associated with wildfire. • Utah is the nation's second driest state. • Can impact farming and ranching operations.
Infestation	• Review of Utah Department of Agriculture and Food Annual Insect Report and the Utah Forest Insect and Disease Report • Input from community members, UDAF, Utah FFSL, and the Utah State University Extension Service	• Consistently affects this region. • Declined forest health and agriculture losses. • Previous experiences have affected the residents of the Wasatch Front. • Results in economic loss. • Destruction can be severe and is very costly to mitigate. • To better understand mitigation and response techniques.
Severe Weather	• Review of County Emergency Operations Plans • Review of past disaster declarations • Input from City and County Emergency Operations Managers, Utah Avalanche, Forecast Center, Utah Department of Transportation, and community members	• Damage to communities, homes, infrastructure, roads, ski areas, and people. • Can cause property damage and loss of life. • Results in economic loss. • Lightning is number one cause of natural hazard death in Utah. • Can be costly to recover from. • Affects the young and old more severely.
Radon	• UGS Maps • Utah Division of Radiation Control Testing Data.	• Is odorless and colorless. • Can cause lung cancer over time.

Table 7-2. Regional Hazards Identification

The hazard identification process was aided through the use of FEMA How to Guidance documents, FEMA 386-1,2,3,7 FEMA Post Disaster Hazard Mitigation Planning Guidance DAP-12, Disaster Mitigation Act of 2000, 44 CFR Parts 201 and 206, Interim Final Rule, and FEMA Region VIII Crosswalk. The risk assessment process also utilized assistance from local Wasatch Front region GIS departments using the best available data.

	Davis County	Morgan County	Salt Lake County	Tooele County	Weber County
Earthquake	X	X	X	X	X
Landslide	X	X	X	X	X
Wildland Fire	X	X	X	X	X
Problem Soils		X	X	X	
Dam Failure	X	X	X	X	X
Flood	X	X	X	X	X
Drought	X	X	X	X	X
Infestation	X	X	X	X	X
Severe Weather	X	X	X	X	X
Radon	X	X	X	X	X

Table 7-3. County Hazard Identification

B. Hazard Profile

This section describes the causes and characteristics of each identified hazard, including its *severity* or *magnitude* (as it relates to the percentage of the jurisdiction that can be affected), *probability*, conditions that make the area prone to the hazard, hazard history, and maps of the hazard's geographic location or extent. The hazards were profiled based on history of occurrence, local input, county emergency operations plans, and county master or general plans, scientific reports, historical evidence, and hazard analysis plans. A risk assessment "Hazard Profile" table was created that highlights the above mentioned materials in each of the county portions of the plan introducing each identified hazard. The probability of a hazard event was determined through the amount of risk to the county. The probability or likelihood of an occurrence is categorized into four categories: Highly Likely, Likely, Possible, and Unlikely.

In determining hazard magnitude a scale was used to identify the level of damage on a countywide basis from Catastrophic to Negligible (Table 7-4).

	Jurisdiction Affected	Risk
Catastrophic	More than 50%	Extreme or High
Critical	25-50 %	Moderate
Limited	10-25%	Moderate
Negligible	Less than 10%	Low

Table 7-4. Hazard Profile

The probability of a hazard event was determined through the amount of risk to the county. The probability or likelihood of an occurrence is categorized into four categories: Highly Likely, Likely, Possible, and Unlikely.

The geographical extent or location of the community that would be affected has been identified in the mapping portion of each county where geographic data was available. Hazard histories are provided for each county. These histories were taken from the Spatial Hazard Events and Losses Database for the United States (SHELDUS). Histories for each county were condensed into charts, tables and graphs in each county hazard profile section.

Maps were created using GIS software to identify the location and extent of each identified hazard area. Hazard maps were created for every identified hazard within the region. The following risk assessment maps were created for each county:

Dam/Reservoir Sites
Earthquake Epicenters and Fault Zones
Flood Zones
Ground-shaking Potential
Landslide Susceptibility
Liquefaction Potential
Problem Soils
Wildfire
Combined Structural Hazards

The following risk assessment maps were created at the regional level:

Drought
Infestation
Severe Weather
Radon

C. Vulnerability Analysis

The vulnerability analysis is based on asset identification and potential loss estimates for those jurisdictions located within identified hazard areas.

Asset Identification

The vulnerability analysis combines the data from each of the hazard profiles and merges it with community asset information to analyze and quantify potential damages from future hazard events. The asset inventory identifies buildings, roads, and critical facilities that can be damaged or affected by the hazard events. Critical facilities are of particular concern because of the essential products and services to the general public they provide. These critical facilities can also fulfill important public safety, emergency response, and/or disaster recovery functions. The critical facilities identified in this plan include hospitals, police and fire stations, schools, communication facilities, utility companies, water and wastewater treatment plants. In order to assess where and to what extent the identified hazards will affect the assets of each county, the locations of assets were identified and overlaid with the mapped hazards using GIS software.

Potential Loss Estimates

Potential dollar loss estimates were identified using this same method; therefore estimates were completed for existing infrastructure only. When data permitted, structure, content, and function of the identified vulnerable infrastructure was incorporated into the vulnerability assessments. Describing the vulnerability in terms of dollar losses provides the community and the state with a common framework in which to measure the effects of hazards on assets.

Future planned development was not analyzed due to the lack of data available in GIS format. However, countywide development trends have been identified and are addressed within Part IV Regional Data. Areas vulnerable to multiple structurally-threatening hazards are mapped in each chapter.

The core planning team and local planning team members estimated potential losses for the identified hazards by using the methodology explained in the FEMA document titled, Understanding Your Risks: Identifying Hazards and Estimating Losses, Utah DHLS historical data and GIS data.

The information sources used to complete the vulnerability assessment portion of this Plan include; Utah DHLS, County GIS departments, county Assessor's Office, HAZUS-MH data, and the Utah Automated Geographic Reference Center (AGRC). This data was compiled into GIS layers that were used as overlays to identify critical facilities, municipalities, roads, and residents. The assets that have been identified are based on the best available data during the development of this Plan in GIS form.

Methodology

Geographic Information System (GIS) software was used as the basic analysis tool to complete the hazard analysis for the Wasatch Front Natural Hazards Pre-Disaster Mitigation Plan. For most hazards a comparison was made between digital hazard data and Transportation Analysis Zone (TAZ) demographic information.

Statewide digital data was obtained from Utah Automated Geographic Reference Center (AGRC) for problem soils only. The vulnerability assessment for each county estimates the number of homes, business, infrastructure and population vulnerable to each hazard and assigns a replacement dollar value to residential structures and infrastructure in each hazard area. The value of residential housing was calculated using estimated average residential housing values for Tooele and Morgan counties, as census estimates were unavailable. All the analysis takes place within the spatial context of a GIS. With the information available in spatial form, it is a simple task to overlay the natural hazards with census data to extract the desired information.

The methodology used to determine vulnerability for all hazards was identical. The number of households and population vulnerable to each hazard was determined using WFRC Transportation Analysis Zone (TAZ) data and Block Data from the 2000 Census data. The Block Data from the 2000 Census database, or TAZ data, was intersected with each of the mapped hazard layers in order to determine the number and location of residential housing units and population at risk from hazards. The methodology used assumes an even distribution of residential housing units and population across each census block. Point data from HAZUS MH was used to determine the number of businesses, and the annual sales of each business in each hazard area.

The number of acres for all hazards was determined for each city and the unincorporated county. Once an acre total was identified it was overlaid on the Census Block data or TAZ data to determine the total number of homes impacted. The number of homes impacted was then multiplied by the average housing value to determine the total value of potential loss. 2006 average house values from the U.S. Census Bureau were used for Davis, Salt Lake and Weber Counties. 2000 U.S. Census Bureau average house values for Morgan and Tooele Counties were multiplied by the rate of increase for Weber County. This produced an average house value of $203,000 for Morgan County and $148,650 for Tooele County. Content values are not included, which would raise the potential loss numbers for housing by approximately 50%.

In addition to the above methodology, earthquake was profiled using HAZUS-MH, which is shorthand for Hazards United States–Multi-hazards. The HAZUS-MH Earthquake Model is designed to produce loss estimates for use by federal, state, regional and local governments in planning for earthquake risk mitigation, emergency preparedness, response and recovery. The methodology deals with nearly all aspects of the built environment and a wide range of different types of losses.

Extensive national databases are embedded within HAZUS-MH, containing information such as demographic aspects of the population in a study region, square footage for different occupancies of buildings, and numbers and locations of bridges. Embedded parameters have been included as needed. Using this information, users can carry out general loss estimates for a region. The HAZUS-MH methodology and software are flexible enough that locally developed inventories and other data that more accurately reflect the local environment can be substituted, resulting in increased accuracy. 2007 TAZ data was aggregated to census blocks to update population data within HAZUS-MH.

Uncertainties are inherent in any loss estimation methodology. They arise in part from incomplete scientific knowledge concerning earthquakes and their effects upon buildings and facilities. They also result from the approximations and simplifications that are necessary for comprehensive analyses. Incomplete or inaccurate inventories of the built environment, demographics and economic parameters add to the uncertainty. These factors can result in a range of uncertainty in loss estimates produced by the HAZUS-MH Earthquake Model, possibly at best a factor of two or more.

The methodology has been tested against the judgment of experts and, to the extent possible, against records from several past earthquakes. However, limited and incomplete data about actual earthquake damage precludes complete calibration of the methodology. Nevertheless, when used with embedded inventories and parameters, the HAZUS-MH Earthquake Model has provided a credible estimate of such aggregated losses as the total cost of damage and numbers of casualties. The Earthquake Model has done less well in estimating more detailed results - such as the number of buildings or bridges experiencing different degrees of damage.

Such results depend heavily upon accurate inventories. The Earthquake Model assumes the same soil condition for all locations, and this has proved satisfactory for estimating regional losses. Of course, the geographic distribution of damage may be influenced markedly by local soil conditions. In the few instances where the Earthquake Model has been partially tested using actual inventories of structures plus correct soils maps, it has performed reasonably well.

The HAZUS Model estimates building losses, numbers of shelters required for displaced households, amounts of debris generated, and numbers of casualties. A HAZUS report was completed for each of the counties covered in this Plan.

The potential impact of natural hazards on transportation and utilities was determined in a similar method as described above. Roads and utilities were overlaid on the hazard areas and the impacted utility and road segments were inventoried. Once the length of vulnerable infrastructure was determined it was multiplied by cost estimate information from HAZUS-MH.

In addition to the linear features, point data for critical facilities, dams, care facilities, schools, power generation facilities and substations were analyzed to determine if the feature was within a hazard area.

Limited availability of digital data presented a problem in completing the vulnerability assessment. Potential loss numbers were only determined for earthquakes, flood, landslides, dam failure, problem soils and wildfires in this Plan. Additional limitations to the above described analysis method include:

- Assuming random distribution
- Limited data sets for water, gas, electrical, resulting in incomplete numbers for these features
- Lack of digital parcels data for Morgan and Tooele Counties
- Relied on state wide data not intended for manipulation at the scale it was used
- Data was not field checked, resulting in an analysis wholly dependent on accuracy of data
- Meta data was lacking on some of the used data sets

In this document, simple maps were created to provide a graphical illustration of location. These maps are done at a scale, which allows them to fit on a standard letter sized page. Data manipulation and maps were created as a planning tool, to be used by interested persons within the WFRC Region. This information should not take the place of accurate field verified mapping from which ordinances need to be based.

Effort to analyze hazards related to potential future development areas was also addressed where applicable. This proved to be a very difficult exercise and at best can only identify areas which need additional research before development should be allowed. No viable source of data exists for this study area to facilitate analysis of future development. Limited zoning data was available, but this data does not necessarily indicate which areas will be developed and which will not.

D. Mitigation Strategies, Objectives, Actions

Using the findings from the risk assessment and the capabilities assessment as a guide, several mitigation strategies and implementing actions were identified that would benefit each jurisdiction. Each action has been formalized and placed into this Plan in each of the county mitigation sections. These actions were identified in the planning group meetings which included input from the core planning team, local planning team, state and local agencies, county government, and city and county residents.

Goals and objectives were developed in a working session between the above-mentioned groups with a period provided for comment and revision.

Each of the jurisdictions identified mitigation actions based on the identified goals and objectives. These actions are included in each county section of this Plan. The mitigation actions identify the responsible agency, the funding source, timeline, background, and their priority. Actions were selected using the information obtained from the capabilities assessment, which identified existing programs and shortfalls related to mitigation activities. The actions were prioritized based on the Social, Technical, Administrative, Political, Legal, Economic, Environmental (STAPLEE) method identified in the FEMA How-To Guides. The STAPLEE method of prioritization emphasizes the effectiveness of the actions with respect to their cost, as well as their social, technical, administrative, political, legal, environmental, and economic effects. Each action is judged and ranked against these criteria and assigned the priority of High, Medium, or Low.

E. Hazard Description

Each of the natural hazards that could affect the Region has been described. These are general descriptions about each hazard to give an idea of what, why, when, and how the hazards occur.

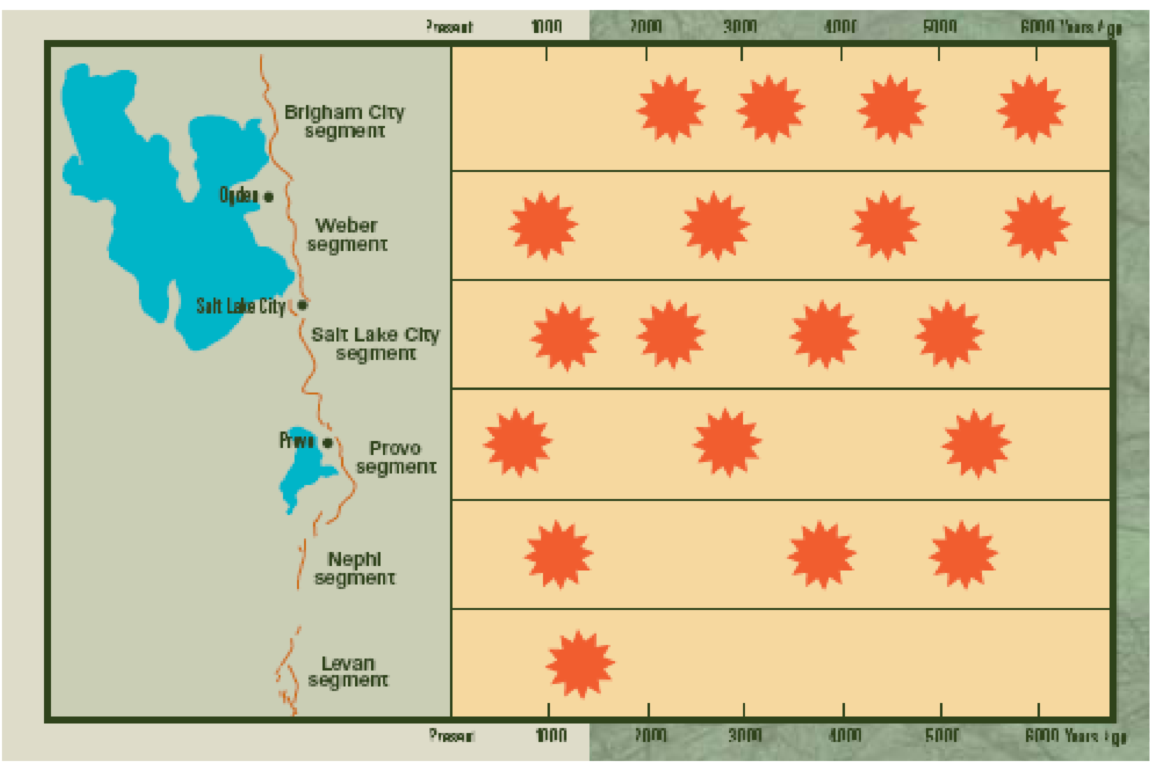

Figure 7-1. Wasatch Fault Segments and Timeline of Major Ruptures (Source: "The Wasatch Fault," Utah Geological Survey)

1. Earthquake

The Utah Geologic Survey defines an earthquake as the result of "…sudden breakage of rocks that can no longer withstand the stresses that build up deep beneath the earth's surface" (UDCEM 1991). The energy that is released is abrupt shaking, trembling or sudden motion in the earth and rocks that break along faults or zone of weakness along which the rocks slip. Seismic waves are then transmitted outward and also produce ground shaking or vibrations in the earth. The Richter scale measures the magnitude of earthquakes on a seismograph. A Richter magnitude 6 earthquake is 30 times more powerful than a Richter magnitude 5. A Richter magnitude 7 is 1000 times more powerful than a Richter magnitude 5.

Utah experiences approximately 700 earthquakes each year, and approximately six of those have a magnitude 3.0 or greater (Table 7-5, this page). On average, a magnitude 5.5 or greater earthquake occurs in Utah every 10 years.

Generally, in order for humans to feel an earthquake it needs to be at least a magnitude 2.0. In order for significant damage to occur, an earthquake needs to be at least a magnitude of 5.5 or greater. The amount of damage that occurs from an earthquake depends on soil type, rock type, ground-water depth and topography. Other factors include the type of construction in an area and the population density.

Locations and Activity: Faulting can be evident on the earth's surface or not evident at all, therefore earthquakes are believed to be able to occur anywhere in Utah (UDCEM 1991).

The earthquake history of the Wasatch Fault is complicated by the fact that we have not had a large earthquake since the first pioneers first arrived in the valley in 1847. The last major earthquake in the Wasatch Front was approximately 1,350 years before present. Yet, when looking at the region, the potential for a large earthquake exists considering that "since 1850 at least 16 earthquakes (excluding aftershocks) of magnitude 6.0 or greater have occurred within the Intermountain Seismic Belt (ISB)" (UDCEM 1991). The greatest earthquake hazard is considered to be in the areas surrounding the Wasatch, East Cache, East Bear Lake, Bear River, Hansel Valley, Northern Oquirrh, West Valley, and East Great Salt Lake fault zones. Other areas of significant hazard along the southern portion of the ISB include the Hurricane, Paragonah, and Sevier faults. The other significant hazard areas in Central Utah are the Stansbury, Joes Valley, and Gunnison faults (UDCEM 1991). On the Wasatch fault, the segments between Brigham City and Nephi, the "composite recurrence interval for large surface-faulting earthquakes (magnitude 7.0 to 7.5) is 395 ± 60 years. The most recent surface-faulting earthquake on the Wasatch fault occurred 400 years ago on the Nephi segment" (UDCEM 1991) (Figure 6-1). The two largest measured earthquakes to occur in Utah were the Richfield earthquake of 1901, with a magnitude of 6.5 and the Hansel Valley earthquake of 1934 with a magnitude of 6.6.

"The Hansel Valley earthquake produced MM intensities of VIII in Salt Lake City, with numerous reports of broken windows, toppled chimneys, and structures twisted on their foundations. A clock mechanism weighing more than 2 tons fell from the main tower of the Salt Lake City County Building and crashed through the building. The only death that occurred during the event was caused when the walls of an excavation collapsed on a public-works employee south of downtown Salt Lake City." (Lund 2005)

	Wasatch Front	**Utah**
Magnitude	***Frequency***	***Frequency***
≥3.0	3 per year	6 per year
≥4.0	1 every 2 years	1 per year
≥5.0	1 every 10 years	1 every 4 years
≥5.5	1 every 20 years	1 every 10 years
≥6.0	1 every 50 years	1 every 20 years
≥6.5	1 every 120 years	1 every 50 years
≥7.0	1 every 330 years	1 every 150 years

Table 7-5. Average Earthquake Frequency *(Source: UUSS unpublished data in UGS PI-38 1996)* *excludes foreshocks, aftershocks and human-triggered seismic events

Utah's most damaging earthquake was of a smaller magnitude (5.7), which occurred near Richmond in Cache Valley in 1962. This earthquake damaged over 75 percent of the houses in Richmond, as well as roads and various other structures. The total damage in 1962 dollars was about one million dollars.

"Earthquakes in 1909, 1914, and 1943 produced MM intensities in Salt Lake City of up to VI, and earthquakes in 1910, 1949, and 1962 had MM intensities of VII in Salt Lake City. Damage produced by these events included broken windows, cracked walls, fallen plaster, toppled chimneys, and buildings shifted on their foundations. The 1949 earthquake also ruptured a water main causing loss of water to a portion of the city." (Lund 2005)

On average, Utah experiences a moderate, potentially damaging earthquake (magnitude 5.5 to 6.5) every 7 years. The history of seismic activity in Utah and along the Wasatch Front suggests that it is not a matter of "if" but when an earthquake will occur.

Secondary Hazards: Associated earthquake hazards include ground shaking, surface fault rupture and tectonic subsidence, soil liquefaction, flooding, avalanches, dam failure, fire, and slope failure.

Ground Shaking: Ground shaking is caused by the passage of seismic waves generated by an earthquake. Shaking can vary in intensity but is the greatest secondary hazard because it affects large areas and stimulates many of the other hazards associated with earthquakes. The waves move the earth's surface laterally and horizontally and vary in frequency and amplitude.

High frequency, small amplitude waves cause more damage to short, stiff buildings. Low frequency, large amplitude waves have a greater effect on high-rise buildings. The intensity depends on geologic features such as bedrock and rock type, topography, and the location and magnitude of the earthquake. Other significant factors include ground water depth, basin shape, thickness of sediment, and the degree of sediment consolidation. Moderate to large earthquake events generally produce trembling for about 10 to 30 seconds. Aftershocks can occur erratically for weeks or even months after the main earthquake event. (UDCEM 1991)

Surface Fault Rupture and Tectonic Subsidence**:** Surface fault rupture or down dropping and tilting associated with tectonic subsidence can rupture the ground surface and in Utah the result is the formation of scarps or steep breaks in the slope. The 1934 Hansel Valley earthquake resulted in a surface displacement of approximately 1.6 feet. The highest potential for surface faulting exists in the central segments of the Wasatch fault. Also, earthquakes having a magnitude of 6.5 or greater could result in surface faulting of 16 to 20 feet high and 12 to 44 mile long break segments. Surface displacement generally occurs over a zone of hundreds of feet wide called the zone of deformation. Tectonic subsidence generally depends on the amount of surface fault displacement. The greatest amount of subsidence will be in the fault zone and will gradually diminish out into the valley (UDCEM 1991).

Soil Liquefaction**:** Liquefaction occurs when there is a sudden large decrease in shear strength of sandy soils. It is caused by the collapse of the soils structure in which the soil loses its bearing capacity, and also by a temporary increase in pore-water pressure, or water saturation during earthquake ground shaking. Liquefaction is common in areas of shallow ground water and sandy or silty sediments. Two conditions must be met in order for soils to liquefy; 1) the soils must be susceptible to liquefaction (sandy, loose, water-saturated, soils typically between 0 and 30 feet below the ground surface) and 2) ground shaking must be strong enough to cause susceptible soils to liquefy (Lips 1999). The result is soils that will flow even on the gentlest of slopes.

Lateral spreading is a type of failure that results in surficial soil layers breaking up and moving, up to 3 feet or more, independently over the liquefied layer. On slopes more than 5 percent, flow failures can move several miles at speeds up to 10s of miles per hour. On slopes less than 0.5 percent the bearing capacity will lessen and can cause buildings to settle or tip. No matter the slope percent, ground cracking and differential settlement will occur. Liquefaction can also cause foundation materials to liquefy and fail and/or cause sand boils. Sand boils are deposits of sandy sediment ejected to the surface during an earthquake along fissures. Liquefaction can occur during earthquakes of magnitude 5.0 or greater. (UDCEM 1991)

Slope Failure**:** Ground shaking can cause rock falls and landslides in mountainous or canyon areas. Rock falls are the most common slope failure and can occur up to 50 miles away from a 6.0 magnitude earthquake. Landslides occur along benches in wet unconsolidated materials. During a 6.0 magnitude earthquake, landslides may occur within 25 miles of the source. (UDCEM 1991)

Flooding: "Flooding can happen due to tectonic subsidence and tilting, dam failure, seiches (waves generated in standing bodies of water) in lakes and reservoirs, surface-water diversion or disruption, and increased ground-water discharge." (UDCEM 1991)

Avalanches: Avalanches could be triggered because of the associated ground movement. The most vulnerable areas include those that have steep terrain, high precipitation, high earthquake potential, and high population density. An example of this area in Utah would be the Wasatch Front (UDCEM 1991).

Sensitive Clays: Sensitive clays are a soil type that loose strength when disturbed and result in liquefaction or collapse. The resulting type of ground failure is similar to liquefaction (UDCEM 1991).

Subsidence: A settling or sinking of the earth's crust in loose granular materials such as gravel that do not contain clay. Western Utah is subject to this type of ground settlement (UDCEM 1991).

Unreinforced Masonry Structures: Unreinforced masonry structures (URM) are a type of building where load bearing walls, non-load bearing walls, or other structures such as chimneys are made of brick, cinderblock, tiles, adobe or other masonry material that is not braced by reinforcing beams. The term is used as a classification of certain structures for earthquake safety purposes, and is subject to some variation from place to place.

URMs are vulnerable to collapse in an earthquake. One problem is that most mortar used to hold bricks together is not strong enough. Additionally, masonry elements may "peel" from the building and fall onto occupants or passersby outside.

URMs were popular when Utah was first settled and continued to be built into the 1970s. The clay material to make bricks was both readily available and familiar to the early settlers. Utah's seismic building codes made substantial improvements in construction in the mid-1970s. Buildings constructed prior to this time may be seismically unsafe. Even some buildings constructed in the 1980s are not as seismically safe as buildings constructed under today's seismic codes. It is not known how many URMs exist in Utah. The Utah Seismic Commissions estimates that there are in excess of 185,000 URMs in the state with Salt Lake County alone estimated to have more than 65,000.

Mitigating the hazards posed by URMs is a difficult and expensive prospect. California enacted a state law in 1986 requiring seismic retrofitting of existing structures. Retrofits are relatively expensive, and may include tying the building to its foundation, tying building elements (such as roof and walls) to each other so that the building moves as a single unit rather than creating internal shear during an earthquake, attaching walls more securely to underlying supports so that they do not buckle and collapse, and bracing or removing parapets and other unsecured decorative elements. Retrofits are generally intended to prevent injury and death to people, not to protect the building itself. The California law left implementation, and standards, up to local jurisdictions. Compliance took many years. Utah has not enacted a URM law similar to California's. In 2008, an eight year seismic retrofit of the Utah State Capitol Building was completed at a cost in excess of $212 million.

2. Flood

It is important to note that flooding is a natural event for rivers and streams. Flood is determined to be the overflow of water onto land that is normally dry. Floods are related to an excess of snowmelt, rainfall, or failure of natural or engineered impoundments onto the banks and adjacent floodplains. Floodplains are lowland areas near river, lakes, reservoirs, oceans, and low terrain urban areas that are subject to recurring floods. Flooding occurs when the peak discharge, or rate of flow in cubic feet per second, is larger than the channel of the river or the storm sewer capacity in a city. The peak discharge for a stream is associated with a probability of occurrence. The probability of occurrence can be stated in terms of recurrence intervals or return periods. For example, a probability of occurrence of 10 percent would be a flood expected to occur once in 10 years or 10 times in a 100 years. Flooding damage includes saturation of land and property, erosion from water, deposition of mud and debris, and the fast flowing waters from the flood itself. Most injuries and deaths occur from the fast moving floodwaters and most of the property damage results from the inundation by sediment-filled water. Flash flood conditions result from intense rainfall over a short period of time (UDCEM 1991).

<u>Snowmelt floods</u> occur from the rapid snowmelt in the mountains. These floods generally happen in April, May and June. Warm air masses with mostly sunny skies melt the mountain watershed snowpack. The large accumulations of water generally last several days and the magnitude depends on the amount of snowpack and the warm weather. Snowmelt flood risk is reduced when the snowpack is below normal and/or the weather changes from winter to spring and summer gradually without an abrupt warming trend (UDCEM 1991).

<u>Rainfall floods</u> result from large amounts of precipitation. Short duration local storms such as cloudburst or thunderstorms with a high intensity rainfall as well as the general storms that last several days with a less intense rainfall can produce a flooding event (UDCEM 1991).

Areas prone to flooding, according to the <u>Utah Natural Hazards Handbook</u>, include lake and reservoir shorelines which may flood when the flow of water into the lakes or reservoirs is greater than the outflow capacity. The Great Basin has several terminal lakes, such as the Great Salt Lake and Sevier Lake, which mean there is no outlet to the sea. These types of lakes are subject to considerable variations in water levels because the only outflow is by evaporation. Successive wet or dry periods lasting several years can result in a large change in size of terminal lakes. Development near this type of lake during a dry period is risky and certain to get flooded during wet periods (UDCEM 1991).

River and creek floodplain areas range from narrow zones to extensive lowlands extending great distances from a natural drainage area. Construction in floodplains is also dangerous because of the high flood risk. It is important to note that the WFRC Region does not have ANY repetitive loss properties.

Urban areas are also prone to flooding because of the decrease in vegetation of the natural watershed. Houses, driveways, parking lots, buildings, and streets are all replacing the vegetative cover that is so important in lessening the potential for flood. This type of development prevents water infiltration into the soil and greatly increases the runoff. In some areas undersized piping and channels are used which may cause flooding. Manmade drainage channels can also play a role in flooding. Trash and debris can obstruct passageways (UDCEM 1991).

3. Landslide

Utah ranked third in the nation in terms of largest total landslide damage cost and cost per person between 1973 and 1983. Utah's landslide hazard rating is "severe", the highest level of five hazard classes given by the U. S. Geological Survey. The three main contributing factors to slope failure include areas with moderate to steep slopes, conductive geology, and high precipitation. The main elements that cause slope failure include precipitation events, topography and vegetation (UDCEM 1991). Landslide distribution in Utah is associated with topography and physiographic provinces. The two physiographic regions that are conducive to landslides in Utah are the Middle Rocky Mountains province and the High Plateaus subdivision of the Colorado Plateau physiographic province. Landslides are also known as slope failure and are classified according to the type of movement and the material involved. The five types of movement include falls, topples, slides, lateral spreads, and flows. The types of materials include rocks, debris (course-grained soil), and earth (fine-grained soil). Slope failure types are identified as rock falls, rock topples, rock slides, debris flows, debris topples, debris slides, slumps, and earth flows (UDCEM 1991).

<u>Rock Falls and Rock Topples</u> occur when loosened blocks or boulders from an area of bedrock move down slope. Rock falls and topples generally occur along steep canyons, cliffs, and steep road cuts. Rock fall damage usually affects roads, railroad tracks, and utilities.

<u>Debris Slides and Debris Flows</u> generally occur in mountainous areas and involve the relatively rapid, viscous flow of course-grained soil, rock, and other surficial materials. Debris flows generally occur in mountainous areas and are considered a flow rather than a slide because of the high water content coupled with the debris. Debris flows are typically more dangerous because of the high speeds under which they form and travel. Debris flows generally remain in stream channels but can flow out from canyon mouths for a considerable distance. Debris flows and slides can damage anything in their path including buildings, roads, railroad tracks, life lines/utilities, and reservoirs.

<u>Slumps</u> are common along road embankments and river terraces. They slip or slide along a curved failure plane away from the upper part of a slope leaving a scarp (a relatively steeper slope separating two more gentle slopes). Slumps generally do not move very far from the source area.

<u>Earth Flows</u> are slumps with the addition of water that slump away from the top or upper part of a slope, leaving a scarp. These can range in size from very small to flows involving hundreds of tons of material and result in a bulging toe that can block streams and cause flooding, and damage buildings or other structures.

Causes of landslides are the result of hillside instability. Slope makeup, slope gradient, and slope weight all play a role. Other important factors of slope instability include rock type and structure, topography, water content, vegetative cover, and slope aspect. Debris flows, for example, occur when these elements are modified by natural processes or by human created processes.

Natural processes that can induce slope failure include ground shaking, wind and water weathering and erosion.

Human created processes such as lawn watering and irrigation may place excess water on already unstable ground by adding water weight to the material and raise the pore pressure, leading to a loss of shear strength. Water can also change the consistency of the slope material reducing cohesion leading to an unstable mixture.

Rock types containing clay, mudstone, shale, or weakly cemented units, which, are strongly affected by weathering and erosion, are particularly prone to landsliding because of expansive and lubricating properties. Other processes include the removal or addition of slope materials during construction. Vegetation is very important in the stabilization of slopes because it prevents rainfall from impacting the soil directly and helps protect from erosion by retaining water and decreasing surface runoff. The roots systems serve as slope-stabilizing elements by binding the soil together or binding the soil to the bedrock. Increase in slope gradient such as placing heavy loads at the top of a slope and /or the removal of material at the toe of a slope all affect the equilibrium and result in slope failure because of slope instability.

4. Wildfire

The Wildland-Urban Interface (WUI) area, or I-Zone, is where residential areas meet wildland areas. It is known as the interface zone and presents a serious fire threat to people and property. The urban aspect includes homes, schools, storage areas, recreational facilities, transmission lines and commercial buildings. Wildland refers to unincorporated areas including hills, benches, plateaus, and forests. Homes are built on the benches adjacent to wildland areas. Wildfires remove vegetation which results in slope failure, erosion, water runoff and depletion of wildlife resources. The three conditions that affect fire behavior are topography, vegetation and weather (UDCEM 1991).

Topography includes such factors as slope, aspect, and elevation. Fires spread faster upslope because the fuels are closer to the flames on the upslope. The heat from a fire moves uphill and dries fuels in front of the fire allowing for easier ignition. The aspect of slope dictates moisture content. In other words, the sun dries out fuels on south and west facing slopes more than on north and east facing slopes. Elevation and weather are interrelated because, generally, higher elevations result in cooler temperatures and a higher relative humidity. Elevation also determines the types of vegetation present (UDCEM 1991).

Vegetation plays a major role in the speed of a fire. Light grasses burn rapidly and heavy dense fuels burn slowly but with a greater intensity. The five major fuel types in Utah's vegetation include grass/sagebrush, pinion-juniper, mountain bush, hardwoods, and softwoods. The grass/sagebrush area poses a serious threat because people under estimate the danger of wildfires in this area. These fires burn across thousands of acres rapidly and pose a serious threat to not only property but also life. Pinion-juniper fuel does not normally burn much, except when conditions are hot, dry and windy. When a fire does occur here, it will burn intensely and spread rapidly. Mountain brush is commonly found in Utah's foothills and when moderate to extreme fire conditions are present; this type of fuel will burn hot and fast. Hardwood-forest and softwood (deciduous) fuel types are generally less risky (UDCEM 1991).

Size, continuity and compactness all affect the fuel's rate of spread. Large fuels do not burn as readily as smaller fuels and need more heat to ignite. Small fuels on the other hand ignite easier, and a fire will spread more rapidly through them. Continuity is described by how fuel is arranged horizontally. Fuels that are broken up burn unevenly and slower than fuels that are uniform. Compactness is how fuel is arranged vertically.

Tall, deep fuels have more oxygen available so they burn more rapidly. Less oxygen is available to compact fuels such as leaf litter and stacked logs; therefore they burn slower (UDCEM 1991).

Weather factors include temperature, humidity, precipitation, and wind. Weather affects the ease with which a fuel ignites, the intensity at which it burns, and how easy or difficult fire control may be.

High temperatures increase fire danger because it heats fuels and reduces water content, which increases flammability. Humidity influences fuel ignition and how intensely fuel burns. A decrease in relative humidity causes fuels to dry, promoting easier ignition and more intense burning. Wind speed can increase burning intensity and the direction that the fire moves. Wind carries heat from a fire into unburned fuels drying them out and causing them to ignite easier. The wind may also blow burning embers into unburned areas well ahead of the main fires starting spot fires (UDCEM 1991).

Fire protection in these areas is difficult because the tactics used for wildland fire suppression cannot be used for structure protection and suppression. The energy that is emitted from a wildland fire is very dangerous to firefighters and homeowners and makes protection of homes almost impossible. One third of all firefighter deaths occur fighting wildfires. Many believe that WUI areas increase the risks to firefighters significantly. Legally, federal wildland protection agencies seldom have the responsibility to protect structures. The legal responsibility for protecting structures on non-federal wildlands varies widely among state forestry agencies (UDCEM 1991).

5. Dam Failure

Dams and associated water delivery systems serve various functions and are built by different agencies and entities including; the Bureau of Reclamation, Army Corps of Engineers, Soil Conservation Service, cities, counties, and private irrigation companies. Dams are built for hydroelectric power generation, flood control, recreation, water storage for irrigation, as well as municipal and industrial uses. Utah's dry climate makes it critical for the storage of the winter snowmelt runoff for uses all year round. 84% of Utah's stored water is behind federal dams, while 650 non-federal dams hold more than 1.2 million acre-feet of water. Dam placement is important and needs to be in an area where it can collect and distribute the greatest amount of water. Dam sites with strong impermeable bedrock are the best in terms of strength. Many materials can be used to construct a dam such as earthen fill, concrete, roller compacted concrete, and rocks and mine tailings. Other dams are created by the enlargement or addition of existing lakes (UDCEM 1991).

<u>Rainy Day failures</u> occur when floodwaters overstress the dam, spillway, and outlet capacities. The floodwater flows over the top of the dam and eventually erodes the structure from the top down. At this point the floodwater meets with the floodwaters from the rainstorm and a very destructive, powerful flood is created" (UDCEM 1991).

Sunny Day failures are the most dangerous because they happen without any warning. Downstream residents or inhabitants have no time to prepare or even evacuate the area; the results are generally catastrophic. Sunny day failures occur from seepage or erosion inside the dam. This erosion removes fine materials creating a large void that can cause the dam to collapse, or overtop and wash away. Earthquake ground shaking or liquefaction can also create structure problems. Ground shaking will cause the dam to start piping, slumping, settling, or experience a slope failure similar to a landslide. The dam then fails internally or overtops and washes away.

Other sunny day failures occur when vegetation or rodents get into a dam and leave holes or tunnels that can lead to failure. Not all dam failures are catastrophic; sometimes a dam can fail and be drained and repaired without a damaging flow of floodwaters (UDCEM 1991).

Hazard ratings are determined by downstream uses, size, height, volume and incremental risk/damage assessments. The hazard ratings are: Low- insignificant property loss; Moderate- significant property loss; and High- possible loss of life" (UDCEM 1991). Over two hundred Utah dams are rated as high-hazard dams.

6. Drought

According to the National Drought Mitigation Center, drought originates from a shortage of precipitation over an extended period of time, usually a season or more. This deficiency results in a water shortage for some activity, group, or environmental sector. "Drought could be considered relative to some long-term average condition of balance between precipitation and evapotranspiration in a particular area" (NDMC 2006). Drought is also related to the timing and effectiveness of precipitation. Drought is a normal, recurrent feature of weather and climate but is a particular concern to all affected because of its devastating outcome. It occurs in almost all climatic zones with varying characteristics. "Drought is a temporary aberration and differs from aridity since aridity is restricted to low rainfall regions and is a permanent feature of climate". Drought is a dry progression through the winter, spring, and summer months that could end in a year or last for many years. The number of dry years correlates with that impacted. Usually, a one to two year drought affects only agriculture, while a three-year drought may significantly impact culinary water in the local areas and communities.

Conceptual definitions of drought help people understand the idea of a drought.

Operational definitions define the process of drought. This is usually done by comparing the current situation to the historical average, often based on a 30-year period of record. It is hard to develop a singular operational definition of drought because of the striking differences throughout the world (NDMC 2006).

Meteorological drought is defined by the degree of dryness in comparison to an average amount and the duration of the dry period. Meteorological drought must be considered as region specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region (NDMC 2006).

Hydrological drought refers to the precipitation decline in the surface and subsurface water supply.
The frequency and severity of hydrological drought is often defined on a watershed or river basin scale (NDMC 2006).

Agricultural drought occurs when there is not enough water available for a crop to grow. This drought links various characteristics of meteorological or hydrological drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, and reduced ground water or reservoir levels (NDMC 2006)

Socioeconomic drought occurs when the physical water shortage begins to affect people (NDMC 2006). When drought begins, the agricultural sector is usually the first to be affected because of its heavy dependence on stored soil water. If precipitation deficiencies continue, then people dependent on other sources of water will begin to feel the effects of the shortage. Those who rely on surface and subsurface water are usually the last to be affected. Ground water users are often the last to be affected by drought during its onset but may be the last to experience a return to normal water levels. The length of the recovery period is a function of the intensity of the drought, its duration, and the quantity of precipitation received as the episode terminates (NDMC 2006).

Measuring Drought:

Palmer Drought Severity Index (PDSI): Developed in 1965, the PDSI is a soil moisture algorithm calibrated for relatively homogeneous regions used by government agencies and states to trigger drought relief programs. The PDSI provides a measurement of moisture conditions that were "standardized" so that comparisons using the index could be made between locations and between months. This is the oldest index for measuring drought and is less well suited for mountainous land or areas of frequent climatic extremes and does not include man-made changes. The PDSI is calculated based on precipitation and temperature data as well as local available water content of the soil. This scale is given as monthly values and is the most effective in determining long-term drought. The index ranges from –4 to 4 with negative values denoting dry spells and positive values indicating wet spells. The values 0 to -.5 equal normal, -0.5 to –1.0 equal incipient drought, -1.0 to –2.0 equal mild drought, -2.0 to –3.0 equal moderate drought, -3.0 to –4.0 equal severe drought, greater than –4.0 equals extreme drought. The wet spells use the same adjectives in the positive values (NDMC 2006).

Surface Water Supply Index (SWSI): Developed in 1982, the SWSI index uses the same basic classifications as the Palmer Drought Index and is designed to complement the Palmer Index in the western states. The SWSI is more of an indicator of surface water conditions and is described as "mountain water dependent", in which mountain snowpack is a major component; calculated by river basin, based on snowpack, stream flow, precipitation, and reservoir storage. The objective of the SWSI was to incorporate both hydrological and climatological features into a single standardized index value. The pros and cons of the SWSI is that the index is unique to each basin. The SWSI is centered on 0 and has a range between –4.2 (extremely dry) and 4.2 (abundant supply). The index is calculated by combining pre-runoff reservoir storage with forecasts of spring and summer stream flow that is based on hydrologic variables (NDMC 2006).

Standardized Precipitation Index (SPI): T.B. McKee, N.J. Doesken, and J. Kleist of the Colorado State University, Colorado Climate Center, formulated the SPI in 1993. The Standardized Precipitation Index was designed to quantify the precipitation deficit for multiple time scales; basically, the SPI is an index based on the probability of precipitation for any time scale. It assigns a single numeric value to the precipitation that can be compared across regions with different climates. The SPI is calculated by taking the difference of the precipitation from the mean for a particular time scale and dividing by the standard deviation. The SPI is normalized and so the wetter and drier climates can be represented in the same way.

The SPI can provide early warning of drought and help assess drought severity, yet the values based on preliminary data may change. The SPI values indicate an extremely wet period value at 2.0+, very wet equals 1.5 to 1.99, moderately wet is 1.0 to 1.49, -.99 to .99 is near normal, -1.0 to –1.49 moderately dry, -1.5 to –1.99 is severely dry, -2 and less is extremely dry. The time scales were originally calculated for 3-, 6-, 12-, 24-, and 48- months (NDMC 2006).

A drought analysis review of 33 gauging stations data in Utah indicated that a localized drought has occurred on at least one stream every year since 1924. The duration of drought lasts longer in basins where runoff is mainly from snowmelt. The frequency of occurrence is greater for areas in the Wasatch Range than in the Wasatch Plateau, the mountains of southwestern Utah, or the Uintah Mountain range. Because Utah relies on surface water supplies, about 81% of the population relies on off-stream water use and 35% of the population relies on surface water supplies, drought severely affects the people and industry of the whole state.

7. Infestation

Infestation has plagued this region since the early 1800-s and continues to be a problem. Infestation is known as a parasite that over-populates in numbers or quantities large enough to be destructive, threatening, or obnoxious. Past infestation events have been devastating enough for presidential disaster declarations because of the destruction to food supplies that affect wildlife, livestock, and agricultural lands including alfalfa, wheat, and barley. Crickets, katydids, grasshoppers, and worms tend to be the most damaging and affect the rural areas the most. With the recent drought in the area the predators have decreased. The drought also affects the food supplies and so the insects begin to search over a wider area when in search of food.

8. Severe Weather

<u>Winter Storm</u>: Winter storms gain energy from the collisions of two air masses. In North America, a winter storm is usually generated when a cold air mass from dry Canadian air moves south and interacts with a northward moving warm moist air mass from the Gulf of Mexico. The position where a warm and a cold air mass meet is called a front. If cold air is advancing and pushing away the warm air, the front is known as a cold front. If warm air is advancing, it will ride up over the cold air mass and the front is known as a warm front. A winter storm will typically begin under what is known as a stationary front. A stationary front is when neither air mass is advancing. The atmosphere will try to even out the pressure difference by generating an area of lower pressure; this creates wind that blows from high pressure towards a low-pressure area.

As the air travels toward the center of the low-pressure area, it is pushed up into the colder regions of the upper atmosphere because it has nowhere else to go. This causes the water vapor to condense as snow in the northern areas because of the colder temperatures. In the south, if the temperatures are warm enough the water vapor will fall as heavy rain in thunderstorms. Because of the easterlies in Northern America, the winter storm moves quickly over the area and generally does not last longer than a day in one area. However, in Utah, because of the Great Salt Lake "lake-effect", snowstorms can last for many days. This is because of the amount of moisture from an unfrozen body of water. When a strong cold wind blows over a larger area of water, the air can attain a substantial amount of moisture; this moisture turns into heavy snow when it reaches land causing a lake effect snowstorm (<u>Scholastic 2008</u>).

Ice Accumulations can bring down electrical wires, telephone poles and lines, trees, and communication towers. Ice can also cause extreme hazards to motorists and pedestrians. Bridges and overpasses are likely to freeze first. (NWS 2001)

Heavy Snow will sometimes "immobilize a region by stranding commuters, stopping the flow of supplies, disrupting emergency and medical services, close infrastructure and services" (NWS 2001). When heavy snow occurs with high winds, blowing snow or blizzard conditions may exist. (NWS 2001).

Avalanche: According to Sandra Eldredge, Utah Geological Survey "a snow avalanche is the rapid down-slope movement of snow, ice, and debris. Snow avalanches occur in the mountains of Utah as the result of snow accumulation and unstable snowpack conditions" (UDCEM 1991). Ground shaking, sound, or a person treading in an avalanche area can trigger a slide that can cover a wide area or can be concentrated to a smaller narrower path.

An avalanche consists of a starting zone, a track, and a runout zone. The starting zone is where the ice or snow breaks loose and starts to slide; this zone can be triggered by human and/ or natural activities. Human induced avalanches can result from snowmobilers, backcountry skiers, or other outdoor recreationalists causing ground shaking. The two main natural factors that affect avalanche activity include weather and terrain and large, frequent storms combined with steep slopes. Other factors that contribute to the stability of the snowpack include the amount of snow, rate of accumulation, moisture content, snow crystal types and the wind speed and direction. The track is the grade or channel down which an avalanche travels. The runout zone is where an avalanche stops and deposits the snow. For large avalanches, the runout zone can include a powder, or windblast zone that extends far beyond the area of snow deposition. In Utah, avalanches annually kill more people than any other natural hazard, and ironically, are often triggered by the victim. Each winter an average of four people dies in Utah due to avalanche activity (UDCEM 1991).

Weather and terrain conditions affect avalanche conditions. The weather controls the durations and the extent of an avalanche while terrain is the element that determines where, why, and how an avalanche occurred. In Utah, the months of January through April pose the greatest avalanche potential. Weather related aspects that affect the snowpack stability include rate of accumulation, amount of snowfall, moisture content, wind speed and direction, and snow crystal type. Wind can deposit snow 10 times faster than snow falling from a storm without accompanying wind. This affects avalanche potential because the underlying weak layer of snow cannot adjust to the new load. Rain and the melting of snow can almost instantly cause an avalanche because of the added weight (UDCEM 1991).

Terrain includes such variables as slope, aspect, elevation, roughness and angle. The slope is important in understanding where an avalanche will occur. Slopes greater than 45 degrees are too steep because the snow continually sluffs off; however slopes greater than 20 degrees can produce avalanches. Optimum slope degree is between 30 to 45 degrees, which is also the optimum angle for backcountry skiers. This slope angle is where approximately 99.9 percent of avalanches occur. The slope aspect and elevation affect the snow depth, temperature, and moisture characteristics of the snowpack. Slope aspect, such as north facing or shady slopes usually produce more avalanches and more persistent avalanche hazards occur during mid winter months. In the spring, the strong sun on south facing slopes produce more wet avalanches (UAC 2008).

Slope shape and roughness correlate with snowpack stability. Roughness identifies boulders, shrubs, and trees that can help slow, or reduce avalanche speed and impact. A bowl shaped slope is more prone to an avalanche than a ridge or cliff.

Dry-slab avalanche is when a cohesive slab of snow that fractures as a unit slides on top of weaker snow and breaks apart as it slides. Dry-slab avalanches occur usually because too much additional weight has been added too quickly, which overloads the buried weak layer. Even the weight of a person can add a tremendous stress to a buried weak layer. Dry-slab avalanches usually travel between 60-80 miles per hour within 5 seconds of the fracture and are the deadliest form of avalanche (UAC 2008).

Wet-slab avalanches occur for the opposite reason of dry avalanches; percolating water dissolves the bonds between the snow grains on the pre-existing snow, which decrease the strength of the buried weak layer. Strong sun or warm temperatures can melt the snow and create wet avalanches. Wet avalanches usually travel about 20 miles per hour (UAC 2008).

Avalanches can result in loss of life as well as economic losses. At risk are some communities, individual structures, roads, ski areas, snowmobilers, backcountry skiers, snowshoers, snowboarders, and climbers. One of the major consequences of avalanches is the burial of structures, roads, vehicles, and people in the runout zone where tens of feet of debris and snow can be deposited (UAC 2008).

<u>Severe Thunderstorms</u> usually last around 30 minutes and are typically only 15 miles in diameter (NWS 1999), but all produce lightning, the "number one weather-related killer" in Utah (NWS 2008). Thunderstorms can also lead to flash flooding from heavy rainfall, strong winds, hail and tornadoes or waterspouts (NWS 1999).

<u>Tornado:</u> Expressed as "a violently rotating column of air extending from a thunderstorm to the ground" (NWS 1999), a tornado is often on the edge of the updraft or next to the air coming down from the thunderstorm. A tornado's vortex is a low-pressure area and as air rushes into the vortex, its pressure lowers and cools the air. This cooler air condenses into water vapor in the funnel cloud, known as the vortex, and doesn't touch the ground. The swirling winds of the tornado pick up dust, dirt, and debris from the ground, which turns the funnel cloud darker. Some tornadoes can have wind speeds greater than 250 miles per hour with a damage zone of 50 miles long and greater than 1 mile wide (NWS 1999). Most tornadoes in Utah typically have winds less than 110 miles per hour, are no wider than 60 feet and are on the ground longer than "a few minutes" (Brough, et al. 2007).

A change in wind direction and an increase in wind speed along with increasing height create a horizontal spinning effect in the lower atmosphere form a tornado while the rising air within the thunderstorm updraft tilts the rotating air vertically resulting in what we call a tornado. The area of rotation is generally 2-6 miles wide and extends through much of the storm (NWS 1999).

> *Scale:* Tornadoes are classified by the National Weather Service using the Fujita Scale, which relates wind speed to damage to determine tornado intensity. The scale uses numbers from 0 through 5 with the ratings based on the amount and type of wind damage (SPC 2007). This scale has recently been modified and is now referred to as the Enhanced Fujita Scale. The Enhanced Fujita Scale classifications are listed below:

Enhanced Fujita Scale
EF-0: 65-85 mph, Light damage, downed tree branches, chimney damage
EF-1: Winds 86-110 mph, Moderate damage, mobile home damage
EF-2: Winds 111-135 mph, Considerable damage, mobile home demolished, trees uprooted
EF-3: Winds 136-165 mph, severe damage, roofs and walls torn down, trains overturned, cars thrown
EF-4: Winds 166-200 mph, Devastating damage, well-constructed walls leveled
EF-5: Winds over 200 mph, incredible damage, homes lifted off foundation and carried, autos thrown as far as 100 feet. (SPC 2007a)

Waterspouts are weak tornadoes that form over warm water, and in Utah generally occur with cold, late fall or late winter storms (Brough, et al. 2007).

Extreme Heat kills more people in the United States each year than any other weather-related hazard (NOAA 2008). Extreme heat is defined as “summertime weather that is substantially hotter and/or more humid than average for a location at that time of year” (EPA 2006). Extreme heat poses multiple threats to persons and infrastructure. Not only may personal health be affected through heat cramps, heat exhaustion or heat stroke (EPA 2006), but power grids are substantially burdened through the increased use of air conditioning, potentially resulting in brownouts or blackouts.

Certain populations are especially vulnerable during these events. These include the very young and elderly, the poor and homeless, reclusive persons, persons with physical or mental impairment, persons using specific medications, illicit drugs or alcohol, or persons strenuously working or playing outdoors (EPA 2006).

Extreme Cold: Prolonged exposure to the cold can cause frostbite or hypothermia and can become life threatening (NWS 2001). Increasing winds can increase the risk to this hazard.

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